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(54) **ELECTRIC POWER SUPPLY SYSTEM**

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(2), (4) Date: **Jun. 3, 2010**

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(57) **ABSTRACT**

An electric power supply system is provided for feeding an output of a DC power source to a load at high efficiency and, without complicated controlling, for allowing for interchange of electric power among a commercial power system, a DC power source and a load.

An electric power supply system includes a DC bus line for connecting a DC generator, a load and system power. The electric power supply system comprises a DC/DC converter connected between the DC generator and the DC bus line for controlling an output voltage to the DC bus line at a voltage V1; an inverter connected between the system power and the DC bus line for operating a control in response to an input voltage V2 from the DC bus line; and an AC/DC converter connected between the system power and the DC bus line for controlling an output voltage to the DC bus line at a voltage V3, wherein the respective voltages are set as V1>V2>V3.

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(51) **Int. Cl.**

**H02J 1/00** (2006.01)

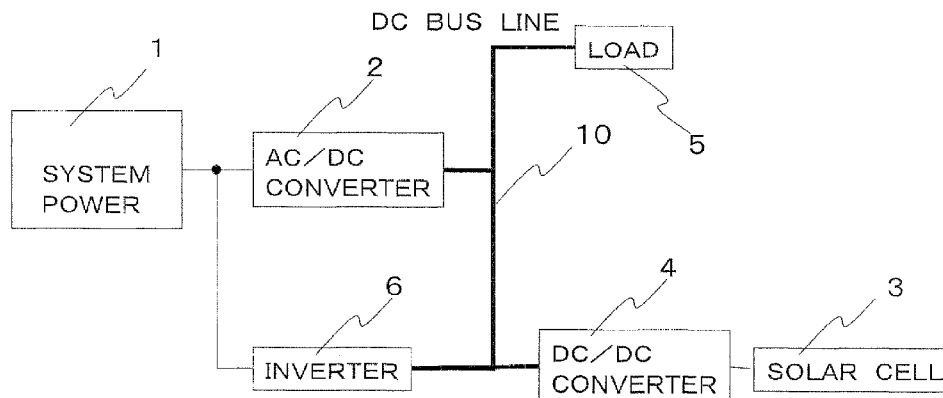
**H02J 3/00** (2006.01)

(52) **U.S. Cl.** ..... **307/75; 363/37; 700/286**

(58) **Field of Classification Search** ..... **307/75, 307/45, 46, 44, 80**

See application file for complete search history.

**5 Claims, 7 Drawing Sheets**



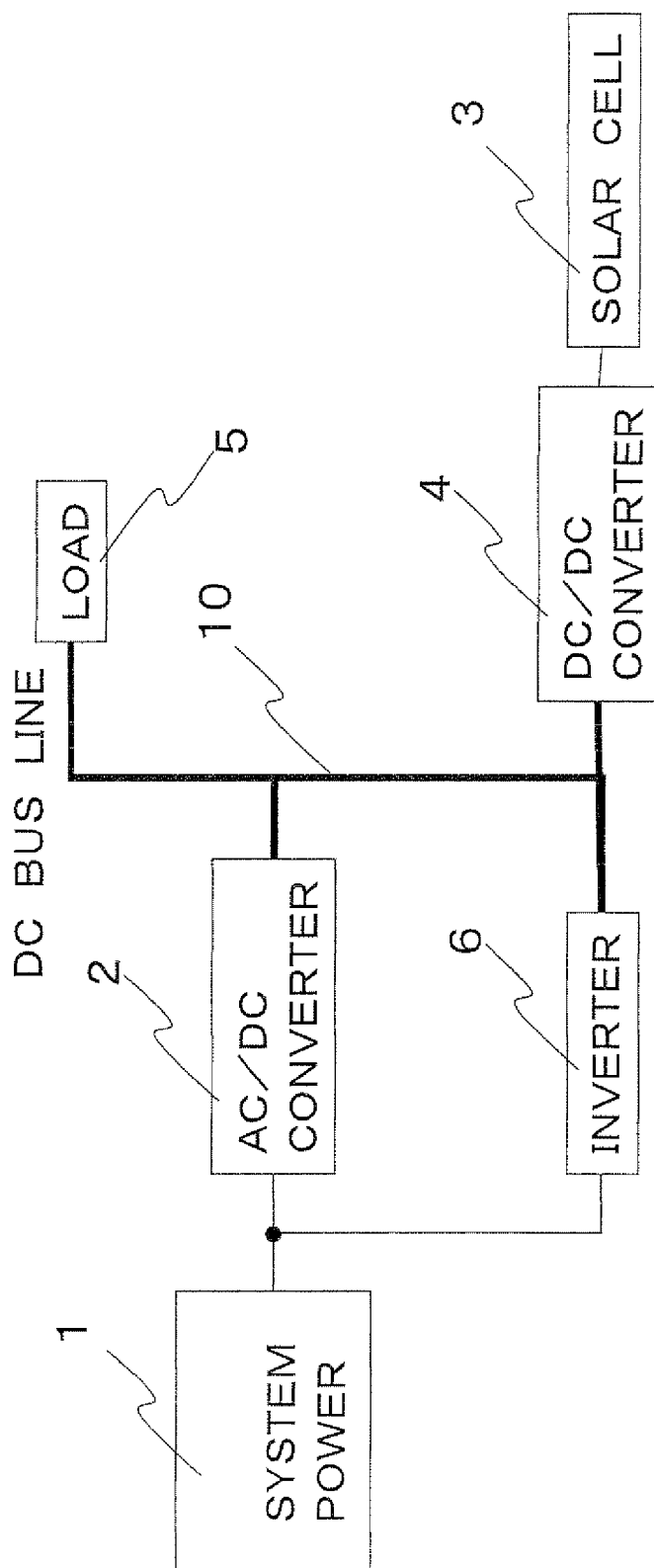


FIG. 1

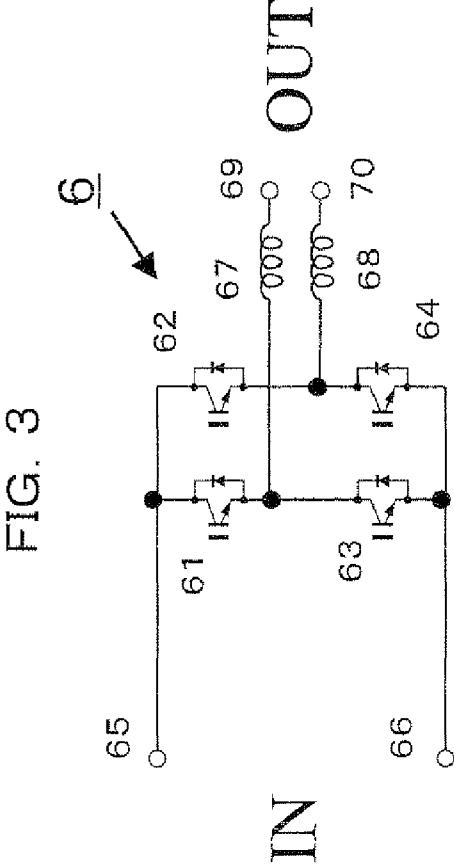
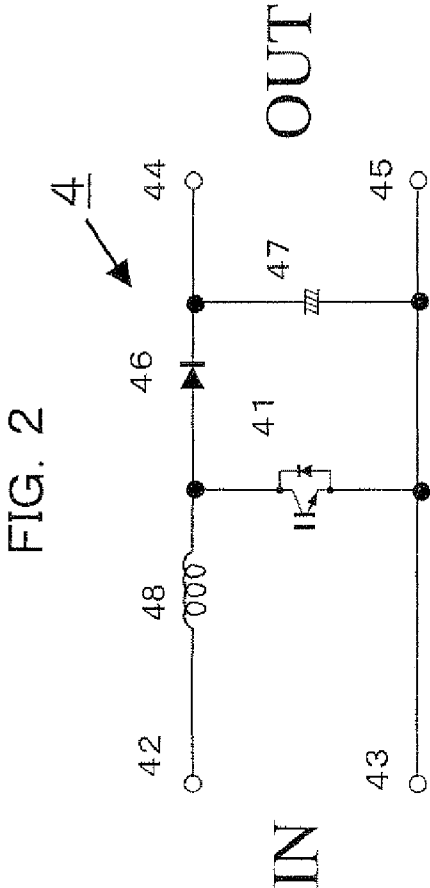
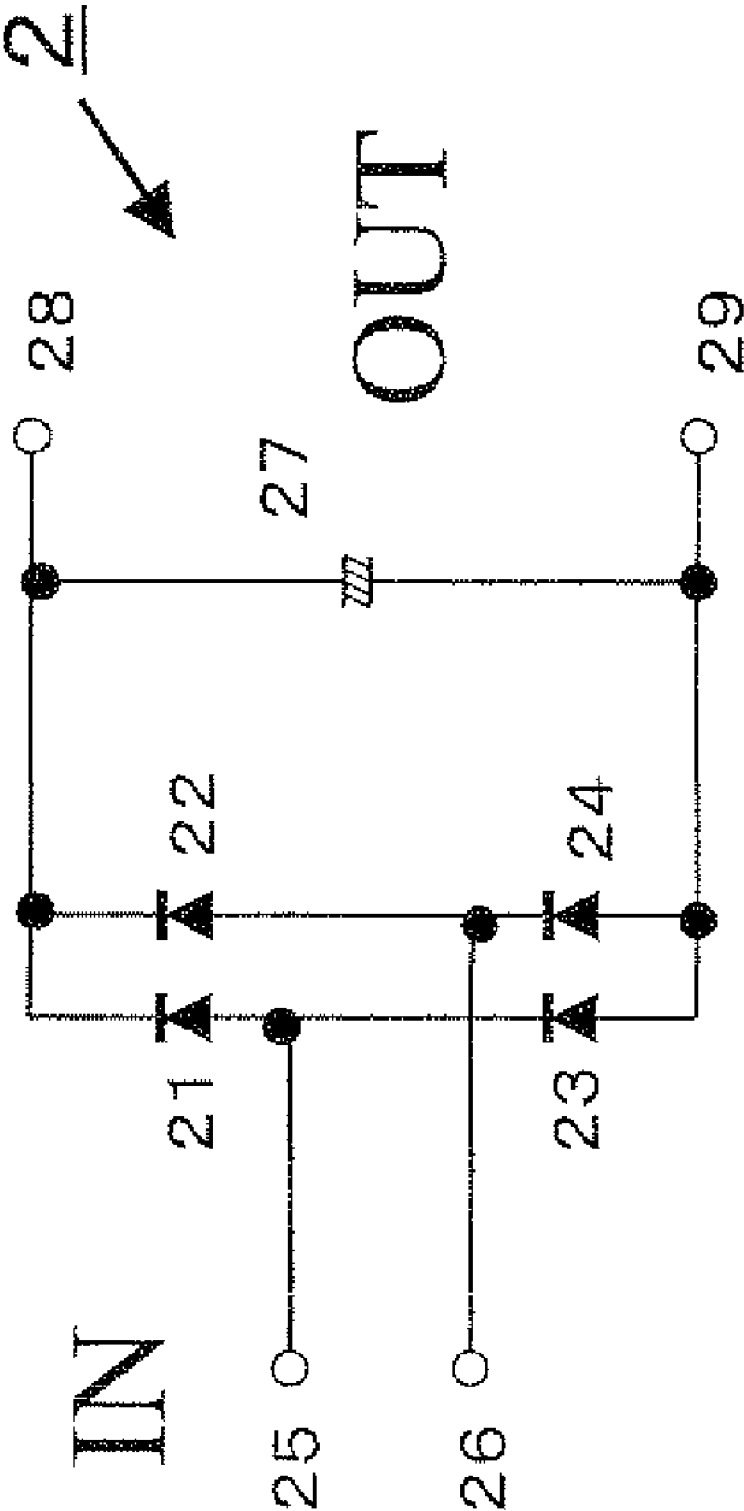


FIG. 4



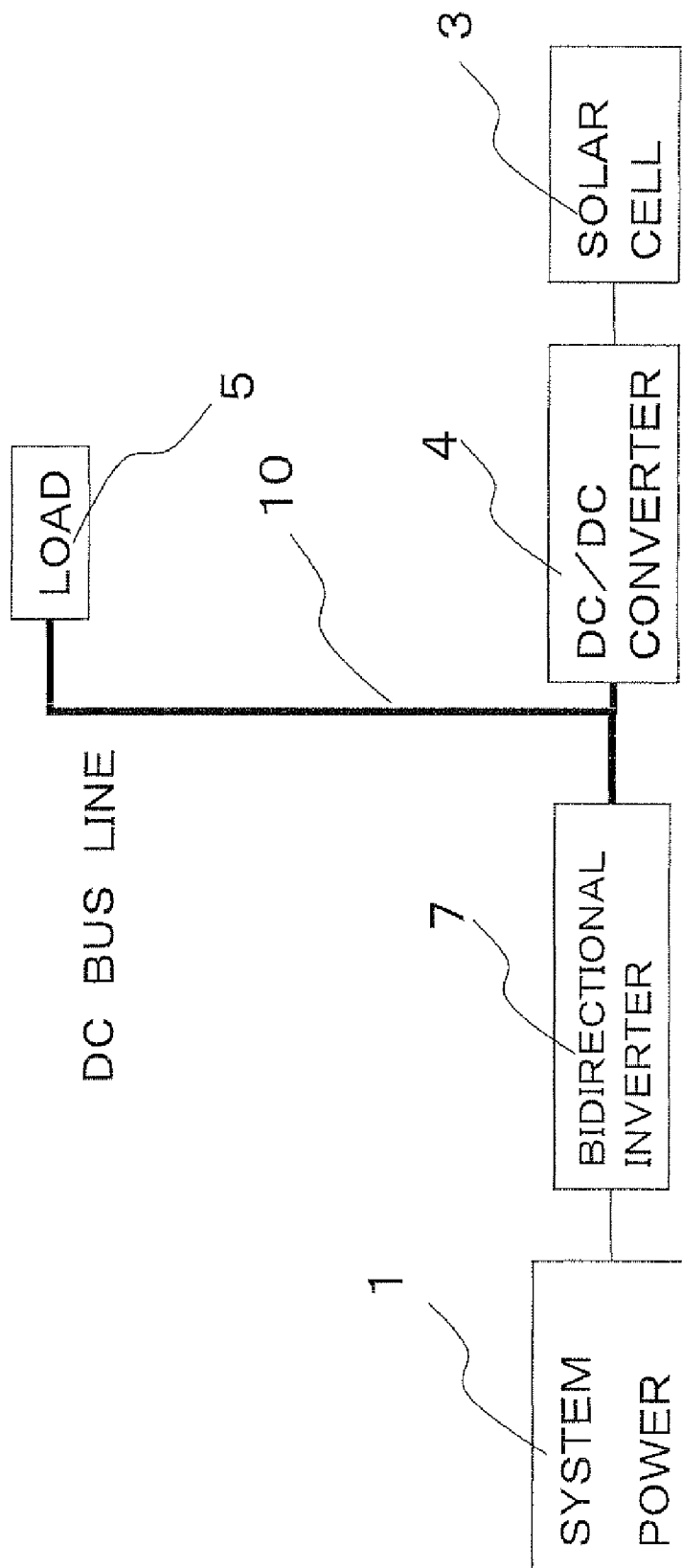
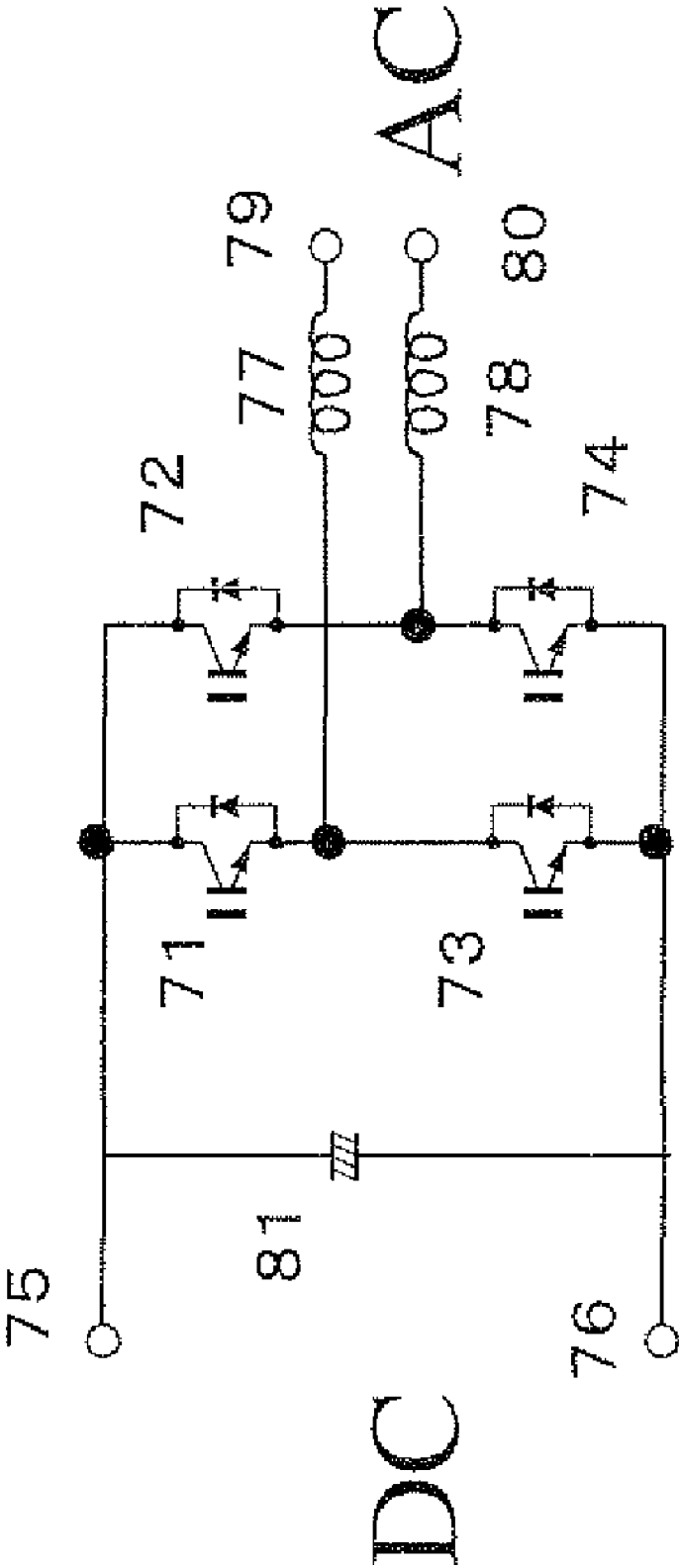


FIG. 5

FIG. 6



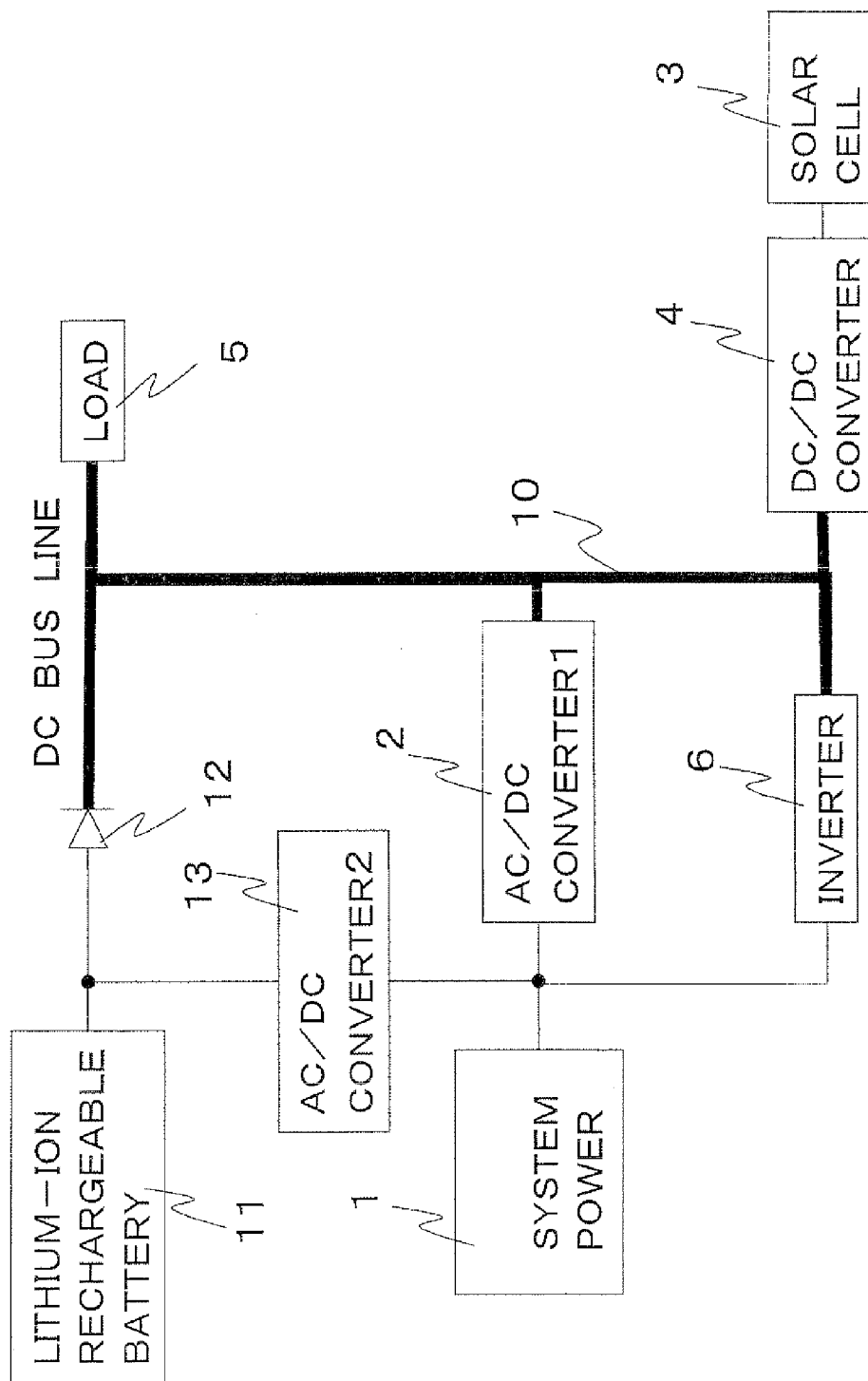


FIG. 7

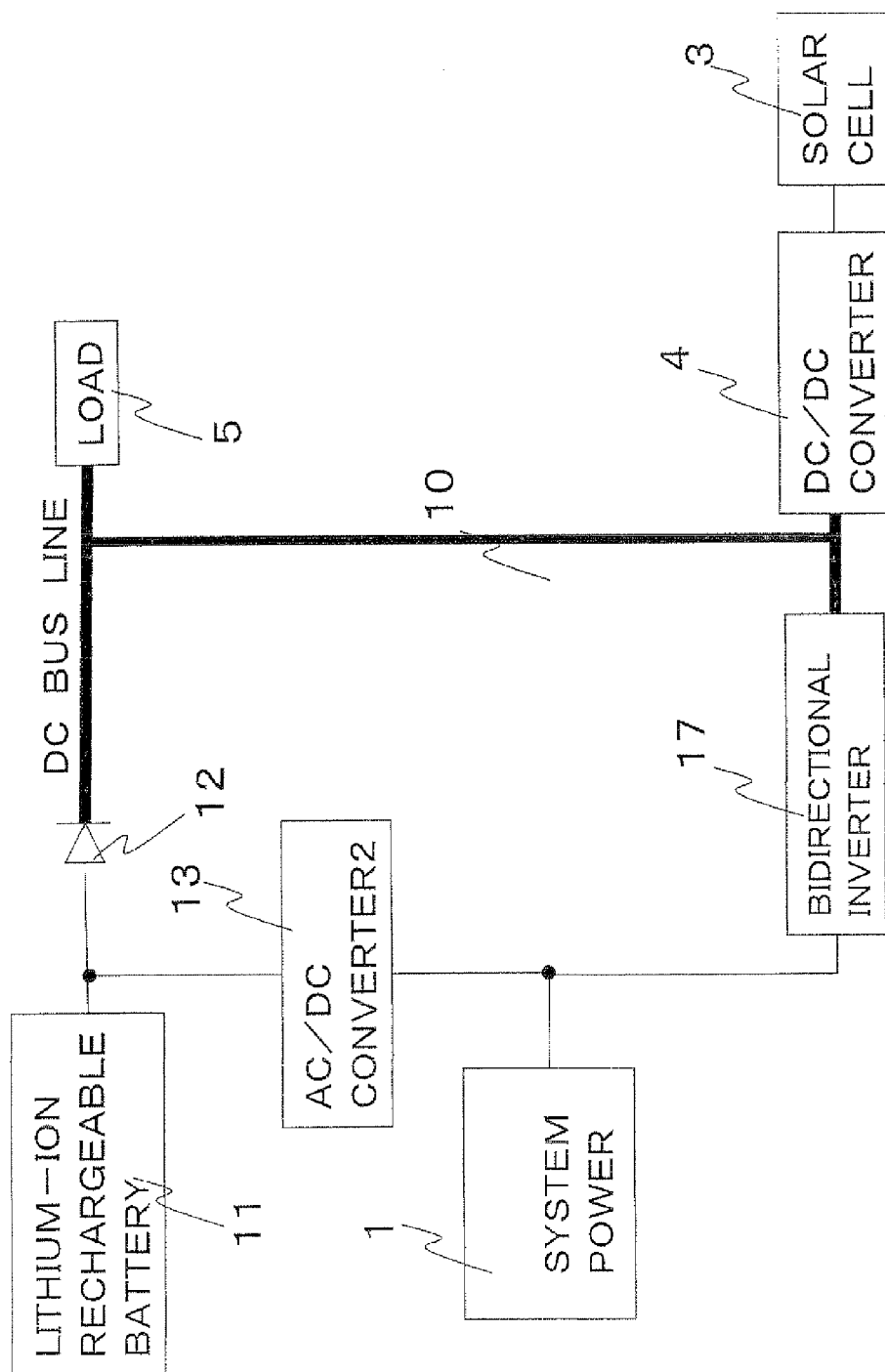


FIG. 8

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**ELECTRIC POWER SUPPLY SYSTEM**

This application is the U.S. national phase of International Application No. PCT/JP2008/071332 filed 25 Nov. 2008 which designated the U.S. and claims priority to JP Patent Application No. 2007-313816 filed 4 Dec. 2007, the entire contents of each of which are hereby incorporated by reference.

**TECHNICAL FIELD**

The present invention relates to an electric power supply system for feeding electric power to a load using a DC generator and system power, and also to an electric power supply system for feeding electric power to a load using a DC generator, a storage battery and system power.

**BACKGROUND ART**

A plenty of techniques for effectively operating an electric power supply system using a DC generator and system power have been developed.

For example, Patent Document 1 shows an electric power supply system for feeding electric power to a load through an electronic transformer commonly operated at operation efficiency of almost 100% by combining natural energy power and nighttime power. More particularly, the rated power voltage of a wind power generator, a photovoltaic generator and a fuel cell is coincident with the rated voltage of a storage battery to construct a DC power source. Until the storage battery is fully charged by the DC power source, AC power is supplied to the load from a commercial AC power source. When the storage battery is fully charged or the commercial AC power source is in a power failure, DC power is supplied from the DC power source and the storage battery. While the storage battery is discharging electric power, power energy is complemented from the fuel cell. During the time of the daylight power supply or the nighttime power supply, AC power is supplied to the load from the commercial AC power source.

Patent Document 2 also shows a construction that an output of a DC generator such as a fuel cell is connected to an DC output of a bidirectional DC-AC power inverter, to which connection a DC outlet is coupled through a DC power conversion device. AC system power and an AC load are coupled to an AC terminal of the bidirectional DC-AC power inverter.

Moreover, Patent Document 3 includes a DC power inverter for inverting DC voltage generated by a fuel cell generator, and an AC-DC power converter for converting AC power to DC power. A DC load and a DC output terminal of the AC-DC power converter are connected to an output terminal of the DC power inverter, and AC system power and an AC load are connected to an AC input terminal of the AC-DC power converter.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2006-254694

Patent Document 2: Japanese Unexamined Patent Application Publication No. 2003-204682

Patent Document 3: Japanese Unexamined Patent Application Publication No. 2007-124830

**DISCLOSURE OF THE INVENTION****Problems to be Solved by the Invention**

However, in the conventional art, an inverter, an AC/DC converter and a DC/DC converter must be controlled even in

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response to output variations of the DC generator, the load variations and the power failure of commercial AC power source (AC power system). A controller is required for this controlling, but the controller necessitates a timepiece and a sensor such as a volt meter in order to control the inverter, the AC/DC converter and the DC/DC converter, and moreover a system must be constructed so as to operate a control in response to the output of the timepiece and the sensor.

In order to solve the above problems, it is an object of the present invention to provide an electric power supply system for feeding an output of a DC power source to a load at high efficiency and, without complicated controlling, for allowing for interchange of electric power among an AC power system, a DC power source and a load, or among an AC power system, an AC power source, a load and a storage battery.

**Means for Solving the Problems**

In order to solve the above problems, an electric power supply system of the present invention includes a DC bus line for connecting a DC generator, a load and system power each other; a DC/DC converter connected between the DC generator and the DC bus line for controlling an output voltage to the DC bus line at a voltage V1; an inverter connected between the system power and the DC bus line for operating a control in response to an input voltage V2 from the DC bus line; and an AC/DC converter connected between the system power and the DC bus line for controlling an output voltage to the DC bus line at a voltage V3, in which the respective voltages are set as  $V1 > V2 > V3$ .

Further, a storage battery is provided which is connected to the DC bus line. When the full charge voltage of the storage battery is V4 and the empty voltage thereof is V5, the respective voltages are set as  $V1 > V2 > V4 > V3 > V5$ .

According to this construction, the voltage value of the DC bus line decides whether or not the DC generator or the system power can supply power to the DC bus line, or power from the DC bus line can be received by the system power. Further, the voltage value of the DC bus line decides whether or not the DC generator, the storage battery or the system power can supply power to the DC bus line, or the power from the DC bus line can be received by the system power.

When the respective voltages are set as  $V1 > V2 > V4 > V3 > V5$ , the order in which to be supplied to the DC bus line is automatically decided as follows. (1) When the voltage of the storage battery is higher than the output voltage of the AC/DC converter, the first is the DC generator, the second is the storage battery and the third is the system power. (2) When the voltage of the storage battery is lower than the output voltage of the AC/DC converter, the first is the DC generator, the second is the system power, and the third is the storage battery.

Therefore, no control device for controlling the DC/DC converter, the inverter and the AC/DC converter is required.

Hence, the above voltage setting enables the power generated by the DC generator to be supplied to the DC bus line with a priority higher than the system power.

Further, the above voltage setting enables the power generated by the DC generator to automatically and reversely be flown to the system power when the generated power is larger than the consumption amount by the load. Nevertheless, the power is not reversely flown from the storage battery to the system power. Besides, the AC/DC converter outputs, as necessary, so as to charge the storage battery. The storage battery can be charged depending upon the charged voltage thereof.

In an embodiment, the electric power supply system of the present invention integrates the inverter and the AC/DC con-

verter to make a bidirectional inverter. Hereby, the number of the components of the electric power supply system can be minimized to construct the system at a lower cost.

#### Effect of the Invention

According to the present invention, the power generated by the DC generator can be supplied to the DC load at high efficiency.

Only when the respective converters and the inverter are independently driven, the interchange of the power among the DC generator, the system power and the load, including the storage battery if it is included, can be properly made, so that no complicated control circuit is required and a highly reliable electric power supply system can be provided at a low cost. Even when the storage battery is equipped, no complicated control circuit is required to prevent the reverse-power flow from the storage battery to the system power.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a system constructed as an embodiment 1 of the present invention.

FIG. 2 is a circuit diagram of a DC/DC converter employed in the embodiment 1 of the present invention.

FIG. 3 is a circuit diagram of an inverter employed in the embodiment 1 of the present invention.

FIG. 4 is a circuit diagram of an AC/DC converter employed in the embodiment 1 of the present invention.

FIG. 5 is a block diagram of a system constructed as an embodiment 2 of the present invention.

FIG. 6 is a circuit diagram of a bidirectional inverter employed in the embodiment 2 of the present invention.

FIG. 7 is a block diagram of a system constructed as an embodiment 3 of the present invention.

FIG. 8 is a block diagram of a system constructed as an embodiment 4 of the present invention.

#### DESCRIPTION OF THE REFERENCE NUMERALS

- 1: system power
- 2: AC/DC converter
- 3: solar cell
- 4: DC/DC converter
- 5: load
- 6: inverter
- 7: bidirectional inverter
- 10: DC bus line
- 11: storage battery

#### BEST MODE FOR CARRYING OUT THE INVENTION

##### Embodiment 1

FIG. 1 is a block diagram of a system constructed as an embodiment 1 of the present invention.

System power 1 is coupled to an AC/DC converter 2, an output terminal of which is connected to a DC bus line 10. A solar cell 3 having a rated output of e.g., 1 kW is connected to the DC/DC converter 4. An output terminal of the DC/DC converter 4 is connected to the DC bus line 10. To the DC bus line 10, a load 5 and an input terminal of the inverter 6 are coupled. An output terminal of an inverter 6 is coupled to the system power 1. Among an output voltage  $V_1$  of the DC/DC

converter 4, an input voltage  $V_2$  of the inverter 6 and an output voltage  $V_3$  of the AC/DC converter 2, a relationship  $V_1 > V_2 > V_3$  is set.

When the electric power supply system of the present invention is for a household use, the load 5 may be one in a house such as an illumination lamp, a television, a personal computer, a record/reproduction device, an audio equipment, an air conditioner, a washing machine, a refrigerator and a cleaner or the like. When it is for an office, the load may be an office equipment such as a photocopying machine, a personal computer, a computer, an illumination lamp and a telephone or the like. When it is for a public facility, the load may be a streetlight, a traffic signal, a sign and a guide map plate or the like. When it is for a factory, the load may be a factory machine such as a motor and a processing machine or the like.

Now, the target voltage of the AC/DC converter 2, the DC/DC converter 4 and the inverter 6, respectively, to the DC bus line 10 will be described in detail with reference to a specific voltage value thereof. These specific voltage values are exemplified only as an example, but not limited thereto.

The DC/DC converter 4 controls to output a voltage of e.g., 210 V to the DC bus line 10. Namely, when the voltage of the DC bus line 10 is lower than 210 V, the DC/DC converter 4 controls to increase the power supply amount from the solar cell 3. To the contrary, when the voltage of the DC bus line 10 is higher than 210 V, the DC/DC converter 4 controls to decrease the power supply amount from the solar cell 3. In this operation, the DC/DC converter 4 controls to keep the output voltage to the DC bus line 10 at 210 V.

The inverter 6 controls to increase an amount of power to demand from the DC bus line 10 so as to cause a reverse-power flow to the system power, when the voltage of the DC bus line 10 is higher than e.g., 200 V. When the voltage of the DC bus line 10 is lower than 200 V, the inverter 6 controls to decrease an amount of power to demand from the DC bus line 10. In this operation, the inverter 6 controls to keep the voltage of the DC bus line 10 at 200 V.

The AC/DC converter 2 controls to output a voltage of e.g., 190 V to the DC bus line 10. That is, when the voltage of the DC bus line 10 is lower than 190 V, the AC/DC inverter 2 controls to increase an amount of power to demand from the system power 1. When the voltage of the DC bus line 10 is higher than 190 V, the AC/DC inverter 2 controls to decrease an amount of power to demand from the system power 1. In this operation, the AC/DC converter 2 controls to keep the voltage of the DC bus line 10 at 190 V.

Next, the operation of the electric power supply system constructed as the embodiment 1 in the case of setting the respective voltages as above will be explained.

The electrical power generated by the solar cell 3 is assumed to be e.g., 1000 W for a sunshiny time. The electric power amount needed by the load 5 at this time is assumed to be e.g., 700 W. Since the electrical power generated by the solar cell 3 suffices the power needed by the load 5, the DC/DC converter 4 controls to supply the power of 700 W to the load 5, and, simultaneously, proceeds to control the voltage of the DC bus line 10 at 210 V. However, when the voltage of the DC bus line 10 is higher than 200 V, the inverter 6 controls to increase an amount of power to demand from the DC bus line 10 so as to cause the reverse-power flow to the system power 1.

As a result, the voltage of the DC bus line 10 becomes 200 V, in which case they are operated in such a condition that the electrical power generated by the solar cell 3 is 1000 W, the power supply amount to the load 5 is 700 W, and the amount of the reverse-power flow to the system power 1 through the inverter 6 is 300 W. Further, since the voltage of the DC bus

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line 10 is 200 V in this case, the AC/DC converter 2 is prevented from outputting to the DC bus line 10.

Successively, the electrical power generated by the solar cell 3 is assumed to be e.g., 500 W. Since the electric power amount of the load 5 is assumed to remain e.g., 700 W, the electrical power generated by the solar cell 3 cannot suffice the power demanded by the load 5. In such a case, the DC/DC converter 4 cannot keep the voltage of the DC bus line 10 at 200 V to lower the voltage. When the voltage of the DC bus line 10 is lower than 190 V, the power is supplied to the load 5 from the system power 1 through the AC/DC converter 2.

As a result, the voltage of the DC bus line 10 becomes 190 V, in which case they are operated in such a condition that the electrical power generated by the solar cell 3 is 500 W, the power supply amount from the system power 1 to the load 5 through the AC/DC converter is 200 W, and accordingly the load 5 consumes 700 W. Further, since the voltage of the DC bus line 10 is 190 V in this case, the reverse-power flow to the system power 1 through the inverter 6 is not caused.

Successively, the electric power amount of the load 5 is assumed to be e.g., 300 W. Since the electrical power generated by the solar cell 3 is assumed to remain 500 W, the same operation as above is performed so that the voltage of the DC bus line 10 is 200 V, the electrical power generated by the solar cell 3 is 500 W, the power supply amount to the load 5 is 300 W, and the reverse-power flow to the system power 1 through the inverter 6 is 200 W.

In this embodiment, the solar cell is exemplified as the DC generator, but any other type power source such as a wind power generator, a fuel cell, a battery or the like may be used as far as it can supply power. Further, the number of the DC generator should not be limited to one, and, for example, both of a photovoltaic generator and a wind power generator can be used.

Further, in this embodiment, the target voltage of the DC/DC converter 4, the inverter 6 and the AC/DC converter 2, respectively, to the DC bus line 10 is differentiated by 10 V, but any voltage value differentiated may be all right or each differentiated voltage value may not be the same. For example, preferably, the differentiated voltage value is 1 to 20 V.

Even if the differentiated voltage value is 1 V, the operation of the system of the present invention can be possible as far as the DC/DC converter 4, the inverter 6 and the AC/DC converter 2 can be operated within their dynamic sensitivity zones. When the differentiated voltage value is 20 V, it is set, for example, that the output voltage of the DC/DC converter 4 from the solar cell 3 is 200 V, the input voltage of the inverter 6 is 180 V, the output voltage of the AC/DC converter 2 is 160 V. Hence, when the output of the DC/DC converter 4 is supplied from the solar cell 3, the power supply to the load 5 is 200 V. Further, when the power supply is from the system power 1 through the AC/DC converter 2, the power supply to the load 5 is 160 V. Thus, the voltage received by the load 5 is varied depending upon the output variations of the solar cell 3. Therefore, if the power supply to the load 5 is excessively varied, the load 5 may become unoperable according to the type thereof or it may be necessary that a DC/DC converter is additionally interposed at the front stage of the load 5 to stabilize the voltage thereof.

Since the load 5 may become unoperable in the case of the large differentiated voltage value, it is necessary to set so that the load 5 is placed in an operative zone. Further, when a DC/DC converter is additionally interposed for stabilizing the voltage, efficiency may be reduced owing to the DC/DC converter, disadvantageously.

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In view of the above, a voltage value of differentiating a voltage of 20 V or more, say, 50 V or 100 V is not preferable. Nevertheless, depending upon the kind of the load 5, some kind of load can be operated under the large differentiated voltage value in which case the differentiated voltage value of 20 V or more may be possible.

As described above, the differentiated voltage value should be decided to the extent that the load is placed in the operative voltage zone and that the presence of the DC/DC converter does not reduce efficiency. Further, the differentiated voltage value may be decided in view of the control capacity and the dynamic sensitivity of the AC/DC converter 2, the DC/DC converter 4 and the inverter 6. Therefore, the differentiated voltage value of 1 V or more and 20 V or less is a preferable one.

In this embodiment, the target voltage of the DC/DC converter 4 to the DC bus line 10 is set to be one voltage like 210 V, but it may be possible to set a predetermined zone such as 210 to 220 V. The target voltage of the AC/DC converter 4 and the inverter 6, respectively, to the DC bus line 10 is similar. In this case, it is prevented that each target voltage to the DC bus line 10 overlaps.

Besides, the above explanation is described assuming that a wiring resistance of the DC bus line 10 is zero, but some wiring resistance actually exists so that the differentiated voltage value should be determined in view of the voltage drop due to the wiring resistance. Further, the electric power supply system according to this embodiment can be operated when the system power 1 is cut off owing to a power failure.

Further, in this embodiment, a DC/DC converter may be placed, if necessary, at the front stage of the load 5. In such a case, the power generated by the solar cell 3 is consumed by the load 5 at the highest priority.

Next, the DC/DC converter 4, the AC/DC converter 2 and the inverter 6 will be described in detail.

FIG. 2 shows the DC-DC converter 4, as a voltage conversion circuit, configured by a boost chopper circuit for boosting the output DC current from the solar cell 3 to 210 V. As shown in FIG. 2, the boost chopper circuit is a general circuit that a switching element 41 is activated in PWM (pulse Width Modulation) at about 20 kHz for boosting the DC voltage inputted across input terminals 42 and 43 to provide a high DC voltage across output terminals 44 and 45. A condenser 47 is a smooth condenser. A reactor 48 is provided. Instead of the circuit elements shown in FIG. 2, a current-resonant type isolated converter, a bidirectional chopper type DC/DC converter, a bidirectional isolated type CukDC/DC converter can be applied.

The boost chopper circuit of FIG. 2 is now described. When the switching element 41 is turned in the on state, the energy is stored in the reactor 48. When the switching element 41 is turned in the off state, the energy stored in the reactor 48 is discharged to charge the energy in an electrolytic condenser 47. The control of the proportion of time between the on and the off states by the switching element 41 enables the voltage inputted from the input terminals 42 and 43 to be boosted to a predetermined voltage (210 V in this embodiment) to output the boosted voltage from the output terminals 44 and 45. In this manner, the DC/DC converter 4 controls the output voltage thereof so as to make the output voltage of the DC/DC converter coincident with the target voltage V1.

The switching element 41 may be used by an MOS FET or IGBT (Insulated Gate Bipolar Transistor).

As shown in FIG. 3, the inverter 6 can be a full bridge circuit comprising four switching elements 61, 62, 63 and 64. These switching elements may be used by an MOS FET or IGBT, which is activated in PWM at about 20 kHz. DC power

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inputted across input terminals **65** and **66** is inverted into an AC voltage by the full bridge circuit and smoothed by reactors **67** and **68**, to output outputted waves of almost the sine waves across output terminals **69** and **70**.

When the system power is coupled to the output terminals **69** and **70** of the inverter **6**, the output voltage of the inverter **6** is decided as the voltage of the system power, so that the inverter **6** is controlled to be operative when the DC voltage across the input terminals **65** and **66** is identical with the decided voltage. Namely, it is controlled as a current type inverter.

The inverter **6** is operated for inverting the DC power to the AC power by exchanging the on state and the off state per half cycle by one pair of the switching elements **61** and **64** and another pair of the switching elements **62** and **63**. The switching elements **61** to **64** control the voltage across the input terminals **65** and **66** by controlling the PWM activation in response to the voltage **V2** of the DC voltage applied across the input terminals **65** and **66**.

As shown in FIG. **4**, the AC/DC converter **2** may be a diode bridge circuit comprising diode elements **21**, **22**, **23** and **24**. AC power inputted across input terminals **25** and **26** is rectified into DC power by the diode bridge circuit and smoothed by the smooth condenser **27**, to output DC power of the voltage **V3** across output terminals **28** and **29**.

#### Embodiment 2

FIG. **5** is a block diagram of a system constructed as an embodiment 2 of the present invention. The embodiment 2 is featured in that the inverter **6** and the AC/DC converter **2** in the embodiment 1 are integrated to make a bidirectional inverter **7** while the remaining points in the embodiment 2 are identical to the embodiment 1.

The bidirectional inverter **7** in the embodiment 2 is operated according to the functions integrated by the inverter **6** and the AC/DC converter **2** in the embodiment 1 in such a manner that when the voltage of the DC bus line **10** is 200 V, the bidirectional inverter **7** causes the reverse-power flow to the system power **1** and when the voltage of the DC bus line **10** is 190 V, the bidirectional inverter **7** permits power to be supplied from the system power **1** to the load **5**. The remaining points are identical to the embodiment 1. A further explanation is omitted here.

FIG. **6** is a circuit diagram of the bidirectional inverter **7**. The bidirectional inverter **7** is different from the inverter as shown in FIG. **2** in that a condenser **81** is connected across terminals **75** and **76** while the remaining are identical thereto.

The bidirectional inverter **7** is operated in such a manner that DC power inputted across terminals **75** and **76** is inverted into an AC voltage by the full bridge circuit and smoothed by the reactors **77** and **78** to output outputted waves of almost the sine waves across terminals **79** and **80**.

The bidirectional inverter **7** is operated for inverting the DC power to the commercial AC power by exchanging the on state and the off state per half cycle by one pair of switching elements **71** and **74** and another pair of switching elements **72** and **73**. The switching elements **71** to **74** invert a voltage of the commercial AC power across the output terminals by controlling pulse widths of the PWM activation in response to the voltage **V2** of the DC power applied across the input terminals **75** and **76**.

When AC power is inputted across terminals **79** and **80**, the switching operations of the switching elements **71** to **74** are not required in which the operation similar to that of the

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AC/DC converter shown in FIG. **4** is performed to output DC power of a voltage **V3** across the terminals **75** and **76**.

#### Embodiment 3

FIG. **7** is a block diagram of a system constructed as an embodiment 3 of the present invention.

The embodiment 3 is differenced in that a storage battery is connected to the embodiment 1. In other words, a lithium-ion battery **11** of 1 kW is connected to the DC bus line **10** through a diode **12** and a second AC/DC converter **13** is coupled across the system power **1** and the storage battery **11**. The other circuit elements are the same as those of the embodiment 1 shown in FIG. **1**. In this embodiment 3, when the full charge voltage of the storage battery **11** is **V4** and the empty voltage thereof is **V5**, the respective voltages are set as  $V1 > V2 > V4 > V3 > V5$ .

Now, in the embodiment 3, the target voltage of the AC/DC converter **2**, the DC/DC converter **4** and the inverter **6**, respectively, to the DC bus line will be described in detail with reference to a specific voltage value thereof. These specific voltage values are exemplified only as an example, but not limited thereto.

The DC/DC converter **4** is controlled to output a voltage of 115 V to the DC bus line **10**. Namely, when the voltage of the DC bus line **10** is lower than 115 V, it controls to increase power supply from the solar cell **3**, and when the voltage of the DC bus line **10** is higher than 115 V, it controls to decrease power supply from the solar cell **3**. In this operation, the DC/DC converter **4** controls to keep the voltage of the DC bus line **10** at 115 V.

When the voltage of the DC bus line **10** is higher than 110 V, the inverter **6** controls to increase power supply demanded from the DC bus line **10** to cause the reverse-power flow to the system power **1**. When the voltage of the DC bus line **10** is lower than 110 V, the inverter **6** controls to decrease power supply demanded from the DC bus line **10**. In this operation, the inverter **6** controls to keep the voltage of the DC bus line **10** at 110 V.

The AC/DC converter **2** is controlled to output a voltage of 80 V to the DC bus line **10**. Namely, when the voltage of the DC bus line **10** is lower than 80 V, the AC/DC converter **2** controls to increase power supply from the system power **1**. When the voltage of the DC bus line **10** is higher than 80 V, the AC/DC converter **2** controls to decrease power supply from the system power **1**. In this operation, the AC/DC converter **2** controls to keep the voltage of the DC bus line **10** at 80 V.

Next, the full charge voltage **V4** and the empty voltage **V5** of the lithium-ion rechargeable battery **11** and the possible influence thereof to the DC bus line **10** will be explained. In the electric power supply system of the embodiment 3, 25 lithium-ion rechargeable batteries are connected in series, in which the full charge voltage of a single one is 4.2 V and the empty voltage thereof is 3 V, so that the total of the full charge voltages is 105 V and the total of the empty voltages is 75 V.

Further, the output voltage of the second AC/DC converter **13** is always governed by the voltage of the lithium-ion rechargeable battery **11**. Since the lithium-ion rechargeable battery **11** is coupled to the DC bus line **10** through a blocking diode **12**, the voltage of the lithium-ion rechargeable battery **11** is lower than the voltage of the DC bus line **10** to provide no influence in the case where the power amount generated by the solar cell **3** is large and the voltage of the DC bus line **10** is higher than 110 V. When the power amount generated by the solar cell **3** is small, the voltage of the lithium-ion rechargeable battery **11** may be possibly equal to the voltage of the DC bus line **10**.

The operation of the second AC/DC converter **13** will be explained. The second AC/DC converter **13** is operated only during the time of the nighttime power of the commercial system power set by the electric power company. Upon the time of the nighttime power, the second AC/DC converter **13** starts to charge the lithium-ion rechargeable battery **11**. Once the charging is completed, the second AC/DC converter **13** stops operating and does not operate until the next time of the nighttime power. Thus, the operation of the second AC/DC converter **13** is thus timed.

Next, the operation of the embodiment 3 in case of setting the voltages as above will be explained.

The voltage of the electrical power generated by the solar cell **3** is assumed to be 1000 W in a morning on a sunny day. The full charge voltage of the lithium-ion rechargeable battery **11** at this time is assumed to be 105 V and the power needed by the load **5** is assumed to be 700 W. Since the electrical power generated by the solar cell **3** suffices the power needed by the load **5**, the DC/DC converter **4** controls to supply the power of 700 W to the load **5**, and, simultaneously, proceeds to control the voltage of the DC bus line **10** at 115 V. However, when the voltage of the DC bus line **10** is higher than 110 V, the inverter **6** controls to increase an amount of power to demand from the DC bus line **10** so as to cause reverse-power flow to the system power **1**.

As a result, the voltage of the DC bus line **10** becomes 110 V, in which case they are operated in such a condition that the electrical power generated by the solar cell **3** is 1000 W, the supply power amount to the load **5** is 700 W, and the amount of the reverse-power flow to the system power **1** through the inverter **6** is 300 W. Further, since the voltage of the DC bus line **10** is 110 V in this case, the AC/DC converter **2** is prevented from outputting to the DC bus line **10**. Similarly, the voltage of the lithium-ion rechargeable battery **11** is 105 V, so that it is prevented from outputting to the DC bus line.

Successively, when the sun goes down, the electrical power generated by the solar cell **3** is assumed to be 500 W. Since the electric power amount of the load **5** is assumed to remain 700 W, the electrical power generated by the solar cell **3** cannot suffice the power demanded by the load **5**. In such a case, the voltage of the DC bus line **10** cannot be kept at 110 V so as to reduce the voltage. When the voltage of the DC bus line **10** is lower than 105 V, the power is supplied to the load **5** from the lithium-ion rechargeable battery **11**.

As a result, the voltage of the DC bus line **10** becomes 105 V, in which case they are operated in such a condition that the electrical power generated by the solar cell **3** is 500 W, the supply power amount from the lithium-ion rechargeable battery **11** to the load **5** is 200 W, and accordingly the load **5** can be operated at 700 W. Of course, when supplying power, the voltage of the lithium-ion rechargeable battery **11** is lowered so that the voltage of the DC bus line **10** is gradually lowered. Further, since the voltage of the DC bus line **10** is 105 V or less in this case, the reverse-power flow to the system power **1** through the inverter **6** is not caused. Further, since the output voltage of the AC/DC converter **2** is 80 V, the system power **1** does not supply power until the voltage of the lithium-ion rechargeable battery **11** is discharged down to 80 V.

Thereafter, the above conditions are continued, so that the voltage of the lithium-ion rechargeable battery **11** is lowered less than 80 V. Then, power of 200 W is supplied from the system power **1** to the load **5** through the AC/DC converter **2**.

Successively, when it is sunny again, the electrical power generated by the solar cell **3** is assumed to be 1000 W. Since the electric power amount of the load **5** is assumed to remain 700 W, the electrical power generated by the solar cell **3** suffices the power needed by the load **5**, again. Thus, as

mentioned above, the voltage of the DC bus line **10** is 110 V so that the reverse-power flow to the system power **1** through the inverter **6** is 300 V.

Thereafter, in the night, the electrical power generated by the solar cell **3** becomes 0 W, but the power needed by the load **5** is increased to 1000 W. In such a case, the voltage of the lithium-ion rechargeable battery **11** is 80 V or less so that power of 1000 W is supplied from the system power **1** to the load **5** through the AC/DC inverter **2**, whereby the voltage of the DC bus line **10** is 80 V.

Thereafter, upon the time of the nighttime power of the commercial system power set by the electric power company, the second AC/DC converter **13** starts to activate. At this time, while the system power **1** charges the lithium-ion rechargeable battery **11** through the second AC/DC converter **13**, the system power **1** supplies power to the load **5**. While the voltage of the lithium-ion rechargeable battery **11** is less than 80 V, the power supply from the system power **1** to the load **5** is performed through the AC/DC converter **2** and when the voltage of the lithium-ion rechargeable battery **11** is 80 V or more, the power supply from the system power **1** to the load **5** is performed through the second AC/DC converter **13**. While the voltage of the lithium-ion rechargeable battery **11** is less than 80 V, the DC bus line **10** is kept at 80 V and when the voltage of the lithium-ion rechargeable battery **11** is 80 V or more, the voltage of the lithium-ion rechargeable battery **11** equals to the voltage of the DC bus line **10**. When the voltage of the lithium-ion rechargeable battery **11** reaches a full charge voltage (105 V), the charge from the system power **1** to the lithium-ion rechargeable battery **11** ends, but for the time of the nighttime power, the power supply is performed from the system power **1** to the load **5**, which needs the power of 1000 W, through the second AC/DC converter **13**. After the end of the time of the nighttime power, the similar operation is repeated from the morning, again.

Also in the embodiment 3, the solar cell **3** is exemplified as the DC generator, but any other type power source such as a wind power generator, a fuel cell, a battery or the like may be used as far as it can supply power. Further, the number of the DC generator should not be limited to one, but, two or more may be possible.

Further, the target voltage of the DC/DC converter **4**, the inverter **6**, and the AC/DC converter **2**, respectively, to the DC bus line **10** and the full charge voltage and the empty voltage of the lithium-ion rechargeable battery **11** may be differentiated 1 to 20 V as explained in the embodiment 1, and, depending upon the kind of the load **5**, they may be more than 20 V.

The target voltage of the DC/DC converter **4**, the inverter **6** and the AC/DC converter **2**, respectively, to the DC bus line **10** may be within a predetermined voltage zone as explained in the embodiment 1. In this case, it is prevented that each target voltage to the DC bus line **10** overlaps.

Further, it may be possible that a DC/DC converter is additionally interposed at the front stage of the load **5** if necessary. In such a case, the power generated by the solar cell **3** is consumed by the load **5** with the highest priority.

Further, the second AC/DC converter **13** is not needed to continue to operate during the time of the nighttime power and it may stop after the lithium-ion rechargeable battery **11** is fully charged. The second AC/DC converter **13** can operate to charge the lithium-ion rechargeable battery **11** for not only the time of the nighttime power, but also the time when it is advantageous for the user including the time when the power is cheap or so. Further, when the power system is abnormal, the second AC/DC converter **13** may be operated so that the power generated by the solar cell **3** is charged through the inverter.

## 11

In this embodiment, the diode 12 is employed as the switching element, but a FET, IGBT or the like can be employed to block a current from the load 5 to the lithium-ion rechargeable battery 11.

The circuits of the DC/DC converter 4, the inverter 6 and the AC/DC converter 2 used for the embodiment 3 are the same as those shown in FIGS. 2 to 4 in the embodiment 1.

## Embodiment 4

FIG. 8 is a block diagram of a system constructed as an embodiment 4 of the present invention.

The embodiment 4 is featured in that the inverter 6 and the AC/DC converter 2 are integrated to make a bidirectional inverter 17 while the remaining points in the embodiment 4 are identical to the embodiment 3.

The embodiment 4 is operated according to the functions integrated by the inverter 6 and the AC/DC converter 2 in the embodiment 3 in such a manner that when the voltage of the DC bus line 10 is 110 V, the bidirectional inverter 17 causes the reverse-power flow to the system power 1 and when the voltage of the DC bus line 10 is 80 V, the bidirectional inverter 17 permits power to be supplied from the system power 1 to the load 5. The remaining points are identical to those in the embodiment 3.

The circuit of the bidirectional inverter 17 is the same as that shown in FIG. 6 in the embodiment 2.

The invention claimed is:

1. An electric power supply system comprising:

a DC bus line for connecting a DC generator, a load and system power with each other;

a DC/DC converter connected between the DC generator and the DC bus line for controlling an output voltage to the DC bus line at a voltage V1;

an inverter connected between the system power and the DC bus line for outputting a voltage V2 from the DC bus line;

## 12

an AC/DC converter connected between the system power and the DC bus line, for outputting voltage V3 for output voltage V3 to the DC bus line; and

a storage battery connected to the DC bus line

wherein when a full charge voltage of the storage battery is V4 and an empty voltage of the storage battery is V5, the respective voltages are set as  $V1 > V2 > V4 > V3 > V5$ , and an order in which power is to be supplied to the DC bus line is automatically decided such that when a voltage of the storage battery is higher than an output voltage of the AC/DC converter, first is the DC generator, second is the storage battery and third is the system power, and when the voltage of the storage battery is lower than the output voltage of the AC/DC converter, first is the DC generator, second is the system power, and third is the storage battery.

2. The electric power supply system according to claim 1, wherein when the output voltage of the DC/DC converter is lower than the voltage V1, the DC/DC converter operates to increase an output thereof and when the output voltage of the DC/DC converter is higher than the voltage V1, the DC/DC converter operates to decrease the output thereof.

3. The electric power supply system according to claim 1, wherein when the input voltage of the inverter is higher than the voltage V2, the inverter operates to increase an output thereof and when the input voltage of the inverter is lower than the voltage V2, the inverter operates to decrease the output thereof.

4. The electric power supply system according to claim 1, wherein the inverter and the AC/DC converter comprise a bidirectional inverter.

5. The electric power supply system according to claim 1, wherein the load is an illumination lamp, a television, a personal computer, a record/reproduction device, an audio equipment, an air conditioner, a washing machine, a refrigerator, a cleaner, a streetlight, an office equipment, a factory machine or the like.

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